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Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

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For the President of the European Patent Office

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(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
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Micro-mechanic thermo structure and method for manufacturing such micro-mechanic structure

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Micro-mechanic thermo structure and method for manufacturing such micro-mechanic structure

The invention relates to a micro-mechanic thermo structure for modulating radiation. The invention further relates to a thermo optical modulator comprising such micro-mechanic thermo structure and a method for manufacturing such a micro-mechanic thermo structure.

Micro-mechanic thermo structures of this type can be used in, for example, switchable mirrors, smart windows, fast imaging devices and optical recording media.

A micro mechanic thermo structure of the type mentioned in the opening paragraph is known from the United States patent US 6,137,623. This document discloses a thermally actuated plate wherein a heater is sandwiched between two polymer layers, whereby the polymer layers have different coefficients of thermal expansion. For example, in case both layers have the same length at a first initial temperature, the length of one layer will vary from the length of the other layer at a different temperature from the initial temperature.

Furthermore, this document discloses a thermo optical modulator comprising a plurality of thermo optical structures positioned on a micro-electronic substrate forming a reflective surface wherein the thermo optical structure introduces a discontinuity in the reflective surface by selectively heating the thermo optical structures so that impinging radiation can be reflected or absorbed.

A disadvantage of the known thermo optical structure is that they are manufactured by conventional micro-electronic or micro-mechanic techniques which requires amongst other several mask steps and etching steps.

It is an object of the invention to provide a micro-mechanic thermo structure as mentioned in the opening paragraph and a thermo optical modulator which can be manufactured by intrinsically simple techniques. To achieve this object, a first aspect of the invention provides a micro-mechanic structure as specified in Claim 1 and a second aspect of the invention provides a thermo optical modulator as claimed in claim 6. The invention is,

inter alia, based on the recognition that in case of an oriented polymer, for example, a liquid crystalline polymerized network, the thermal expansion of the aligned liquid crystalline polymerized network in a direction parallel to the molecular director differs from the thermal expansion in a direction perpendicular to the molecular director. In case the two layers of the micro-mechanic thermo structure are adhered to each other, a change of temperature will lead to bending of the micro-mechanic thermo structure. This thermal expansion behavior is reversible.

In this application director means the average direction of the longitudinal axis of the oriented polymer molecule.

In case more than one micro-mechanic structure is made on a single substrate a thermo optical modulator can be obtained. A thermo optical modulator is based on the fact that the polymer layers of each micro-mechanic thermo structure are provided with an absorbing dye or a reflecting coating and are oriented on a transparent substrate in a way that, in a first state at a first temperature, the micro-mechanic structures are capable to shut off a portion of an underlying surface and to stop incident light and, in a second state at a second temperature, they are capable to transmit a portion of the incident light via the transparent substrate.

A particular advantageous embodiment is specified in claim 2. Liquid crystalline polymerized material are the reaction products of monomers or of a mixture of monomers comprising a reactive group. Such polymeric materials have the advantage that the liquid crystalline groups can be oriented prior to polymerization. Polymerization causes such an orientation to be frozen as it were in its initial state wherein the orientations has been induced. This liquid crystalline materials are known per se from the published international patent application WO97/44409.

A further embodiment is specified in claim 3. In this embodiment a mechanically coupling is obtained intrinsically when a bilayer structure is made from a single layer of polymer material having a twisted director pattern. This embodiment can be made by photoreplication from a mould that is provided with an orientation inducing layer that establish a different, but well-controlled molecular orientation in the monomeric state of the liquid crystalline monomers that is subsequently fixed in the photopolymerization process.

It is a further object of the invention to provide a method of manufacturing micro-mechanical thermo structures as mentioned in the opening paragraph which is relatively simple to apply. This object is achieved by the method as specified in claim 9. In this way, a thermo optical modulator or a micro-mechanic thermo structure can be made by

photoreplication from a mould that is provided with an orientation inducing layer that establish a different, but well-controlled molecular orientation in the monomeric state of the liquid crystalline monomers that is subsequently fixed in the polymerization process.

Further advantageous embodiments are specified in the dependent claims.

These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter.

In the drawings:

Fig.1 shows a known polymeric bilayer element,

Fig. 2 shows a schematic polymer network of C6H and C10H,

Fig. 3 shows a graph of the thermal expansion poly C6H and the poly C10H liquid crystalline networks,

Fig. 4 shows diagrammatically a twisted liquid crystalline network that will bend when the temperature is changed,

Fig. 5 shows a process steps of a replication process for making a twisted liquid crystalline molecular structure,

Fig. 6 shows diagrammatically a thermo optical modulator and

Fig. 7 shows a transmission- temperature diagram of a thermo optical modulator as a function of temperature.

Fig. 1 diagrammaticaly shows a micro-mechanic thermo structure 10 comprising two layers 12,14 of oriented polymer material of length h and thickness d_1 and d_2 respectively, with different thermal expansion coefficients in a first direction and in a second direction respectively. The director n1 of the molecules of the oriented polymer of the first layer 12 is perpendicular to the director n2 of the molecules of the oriented polymer of the second layer 14. Preferably, the oriented polymers have been made from liquid crystalline monomers.

Furthermore, the first and second layers 12,14 can be made of the same liquid crystalline polymerized material. In this liquid crystalline polymerized material, the thermal expansion in a certain direction depends on the orientation of that direction with respect to the director of the molecules in the liquid crystalline polymerized networks. In this example,

the expansion coefficient in the direction is the largest in the direction coinciding with the director of the molecules in the liquid crystalline polymerized networks.

Fig.2 shows a molecular diagram 16 of polymerized network of suitable liquid crystalline materials C6H and C10H.

Fig.3 shows a graph of the thermal expansion as a function of temperature of two liquid crystalline networks formed by polymerization of monomers C6H and C10H in the oriented state. The line 20 indicates the thermal expansion for polymerized C6H in a direction perpendicular to the director and the line 22 indicates the thermal expansion for polymerized C6H in a direction parallel to the director.

The line 24 indicates the thermal expansion for polymerized C10H in a direction perpendicular to the director and the line 26 indicates the thermal expansion for polymerized C10H in a direction parallel to the director. From Fig.3 the differences in thermal expansion in the predetermined directions are obvious. So, when two, at room temperature straight, layers of the liquid crystalline polymerized material, but with perpendicular oriented directors, have been adhered to each other in order to form a micro-mechanic thermo structure, these layers are enforced to bend at a temperature change. This is caused by the difference in thermal expansion. The thermal expansion in the layer in the direction perpendicular to the director is high and the thermal expansion in the layer parallel to director is low and even may become negative.

Fig. 4 shows a micro-mechanic thermo structure 40 made of a single layer of a liquid crystalline polymerized material with a twisted director pattern 42, wherein the mechanical coupling between the two layers is obtained intrinsically. At a higher temperature, for example, one side 44 expands along the line 46, the opposite side 48 of the layer contracts along the line 50. As a result the layer bends in a direction along the line 52.

Fig. 5 shows a flow diagram of a manufacturing method for micro-mechanic thermo structures with a twisted molecular arrangement. In a first step 54, a mould 56 with the desired surface relief 58 depending on the outlines of a wished micro-mechanic thermo structure is provided with a orientation inducing layer 60. For example by coating the surface relief 58 with a photo-alignment layer 60. Suitable photo-alignment layers can be used to provide the mould 56 with orientation layer that on a local scale provide a predetermined molecular orientation of the liquid crystalline monomer. These photo-alignment layers are, for example, based on cinnamic esters, that can undergo an anistropic 1,2 cyclo-addition by exposing with polarized light. These photo-alignment layers are known from "Photoalignment and photo-patterning of planar and homeotropic liquid-crystal-display

configuration" by H. Sieberle and M. Shadt, Journal SID, 8/1, 67-70, 2000 and "Photoinduces surface alignment for liquid crystal displays" by M. O'Neill and S.M. Kelly in Journal of Physics D: Appl. Phys., 33, R67-R84, 2000.

Alternatively, the photo-alignment layers can be based on photo-sensitized polyimides that, by photoreactions selected by a person skilled in the art, provide the anisotropy to align the liquid crystalline material that are brought in contact with the photo-alignment layer 60. Photo-alignment layers are commercially available and can be obtained from Vantico, JSR and Nissan.

In a subsequent step 62, the surface relief 58 is exposed with ultra-violet light with a first linear polarization direction. In a further subsequent step 64, the surface relief is exposed with ultra-violet light having a second linear polarization direction, different from the first polarization direction. These exposures provide a predetermined orientation inducing structure at the mould surface relief 58. It is also possible to apply a photo-alignment layer that orients liquid crystalline molecules perpendicular to the surface of the mould 56 without exposure and align the liquid crystalline molecules in a predetermined planar direction upon ultra-violet exposure. This type of photo-alignment has the advantage that only a single exposure is required during the mould preparation, to provide a predetermined director orientation in the reactive liquid crystal monomers.

In a further subsequent step 66, a substrate 68 is positioned opposite the mould 56 and a reactive liquid crystalline monomer 70 is pressed between the mould 56 and a substrate 68. After a waiting period, wherein the predetermined molecular orientation in the liquid crystalline monomer is obtained, the monomer is polymerized by exposing with ultra-violet radiation. Preferably, during the waiting period, a thermal annealing step can be applied for promoting the obtaining of the predetermined molecular orientation of the liquid crystalline monomer. A suitable liquid crystalline monomer is C6H or C10H.

In a further subsequent step 72, the mould 54 is removed and the micro-mechanic thermo structure 73 is obtained. The mould 54 in Fig. 5 forms a single micro-mechanic thermo structure 73. However, it is also possible to form a mould for arrays of micro-mechanic thermo structures on a single substrate to manufacture a thermo optical modulator.

Fig.6 shows a thermo optical modulator 74 comprising polymer walls 75. At a first temperature, the polymer walls 75 are perpendicular to a preferably transparent substrate 76. Preferably, the polymers wall 75 are provided with a reflective coating (not shown). For

example Al, Ag or Au. Is also possible to provide the polymer walls 74 with an absorbing coating (not shown), for example CrO2.

Alternatively, the polymer wall 75 can be made self absorbing by adding a dichroic guest-host dye such as iodine polyvinylacetate applied in polarizers conventionally used in liquid crystalline display devices. In the undeformed state, the polymer walls 75 are straight and the thermo optical modulator 74 transmits substantially all incident light 77 via the transparent substrate 72. In a second deformed state, at a second, higher, temperature, the polymer walls 72 of the thermo optical modulator 74 are bend and thereby will block substantially all the incident light 77. The opposite arrows indicates the reversibility of the switching process when the temperature returns to its initial value.

The transmission of this thermo optical modulator can be calculated using formula (1)

$$Tr = \frac{p-(d_1+d_2)-\xi}{p}.100\% \qquad (1)$$

Wherein

Tr represents the transmission,

p represents the pitch or distance between adjacent polymer walls on the substrate,

d_1, d_2 represent the thickness of the first and second layers respectively of each wall, and

ξ represents the projected deformation.

The projected deformation can be estimated from γ_1 and γ_2 the thermal expansion coefficient perpendicular and parallel to the director, respectively, by using formula (2)

$$\xi = r\left[1-\cos\left(\frac{h}{r}\right)\right] \qquad (2)$$

Wherein h represent the height of the polymer wall and r is calculated by formula (3)

$$r = \frac{d_1(1+\gamma_2\Delta T)+d_2(1+\gamma_1\Delta T)}{(\gamma_1-\gamma_2)\Delta T} \qquad (3)$$

For liquid crystalline polymerized materials the thermal expansion coefficients γ_1 and γ_2 start to deviate from each other around the glass transition temperature of the composing polymers. As a result, the transmission around this glass transition temperature exhibits a sharp transition. This is modeled for a thermo optical modulator having different wall geometries.

Fig.7 shows a graph 81 representing the transmission of a thermo optical modulator as a function of the temperature of the thermo optical modulator for a device having a constant pitch *p* of 20 micrometer and a thickness d_1,d_2 of 2 micrometer for different heights. The lines 82-85 show the transmission *Tr* as a function of temperature *T* for a height *h* of the polymer wall of 10, 20, 30 and 40 micrometer, respectively.

Furthermore, Fig. 7 shows a graph 86 representing the transmission of a thermo optical modulator as a function of the temperature of the thermo optical modulator for a device having a constant height *h* of 30 micrometer and a thickness d_1,d_2 of 2 micrometer for different pitches. The lines 87-90 show the transmission *Tr* as a function of temperature *T* for a pitch *p* of the polymer wall of 10, 20, 30 and 40 micrometer, respectively.

It will be obvious that many variations are possible within the scope of the invention without departing from the scope of the appended claims.

CLAIMS:

1. A micro-mechanic thermo structure for modulating a light beam comprising two layers of material with different thermal expansion coefficients in respective a first direction and a second direction, whereby the first direction is transverse to the second direction and the two layers comprising an oriented polymer whereby the director of the molecules of the oriented polymer of the first layer is transverse to the director of the molecules of the oriented polymer of the second layer.

2. A micro-mechanic thermo structure as claimed in claim 1 wherein the oriented polymer comprises a liquid crystalline polymeric material.

3. A micro-mechanic thermo structure as claimed in claim 1 wherein the two layers are constituting a single layer wherein the director of the liquid crystalline molecules at one side of the single layer is rotated with respect to the director of the liquid crystalline molecules at the opposite side of the single layer.

4. A micro-mechanic thermo structure as claimed in claim 3 wherein the angle between the director of the liquid crystalline molecules at one side of the single layer is rotated 90 degrees with respect to the director of the liquid crystalline molecules at the opposite side of the single layer.

5. A micro-mechanic thermo structure as claimed in claim 1 as claimed in wherein the director of the liquid crystalline molecules is parallel to the layers.

6. Thermo optical modulator comprising a plurality of micro-mechanic thermo structures as claimed in claim 1 ordered on a substrate.

7. Thermo optical modulator as claimed in claim 6 wherein the layers are provided with an reflective coating or an absorbing coating.

8. Thermo optical modulator as claimed in claim 6 wherein the oriented polymer layers comprising a dichroic guest-host dye for absorbing light.

9. Method of manufacturing a micro-mechanic thermo structure comprising the steps of:

- shaping a mould with a desired surface relief for replicating the shape of the micro-mechanic thermo structure;
- providing the mould with an orientation inducing layer for obtaining a molecular orientation in the monomeric state of liquid crystalline monomers,
- pressing a reactive liquid crystalline monomeric material between the mould and a substrate;
- polymerizing the liquid crystalline monomeric material;
- releasing the mould from the substrate whereby the micro-mechanical thermo structure at the substrate is obtained.

10. Method of manufacturing a micro-mechanic thermo structure as claimed in claim 9, wherein the step of providing the mould with an orientation inducing layer comprises further steps of:

coating the surface of the mould with a photo-alignment layer; and

exposing the photo-alignment layer with UV radiation for obtaining a structure inducing a predetermined direction of the director of the liquid crystalline molecules at the mould surface.

11. Method of manufacturing a micro-mechanic thermo structure as claimed in claim 7, wherein the step of exposing the photo-alignment layer comprises two sub-steps of

- exposing the photo-alignment layer with ultra-violet radiation with a first linear polarization direction; and
- exposing the photo-alignment layer with ultra-violet radiation with a second linear polarization direction which second polarization direction is different from the first polarization direction.

ABSTRACT:

The invention relates to a micro-mechanic thermo structure for modulating a light beam and a method for manufacturing such structure. The micro-mechanic structure comprises two layers of material with different thermal expansion coefficients in respective a first direction and a second direction, whereby the first direction is transverse to the second direction and the two layers comprising an oriented polymer and the director of the molecules of the oriented polymer of the first layer is transverse to the director of the molecules of the oriented polymer of the second layer. An array of such micro mechanic structures may form a thermo optical modulator for modulating light.

The method comprises a step of provided a mould with an orientation inducing layer for obtaining a molecular orientation in a mono-meric state of liquid crystalline monomers and a step of fixing the molecular orientation by photo-polymerization.

Fig. 4

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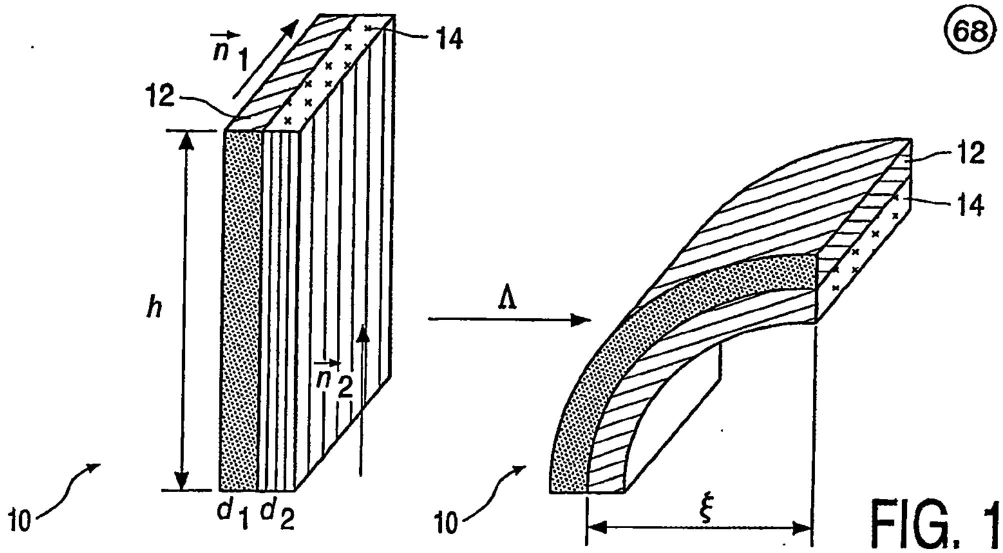

FIG. 1

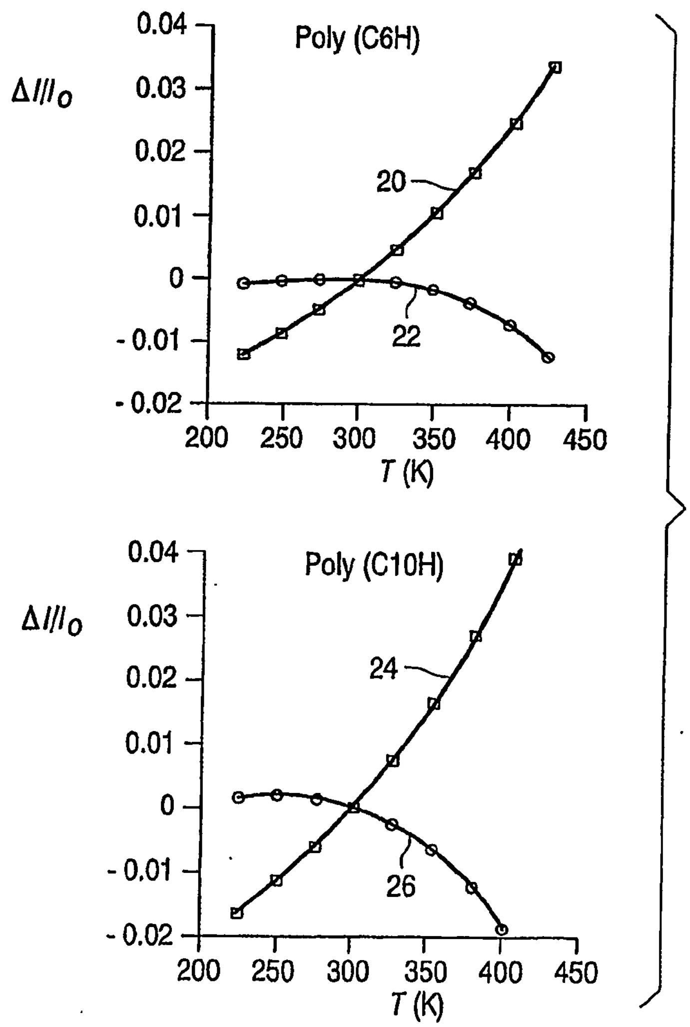

FIG. 3

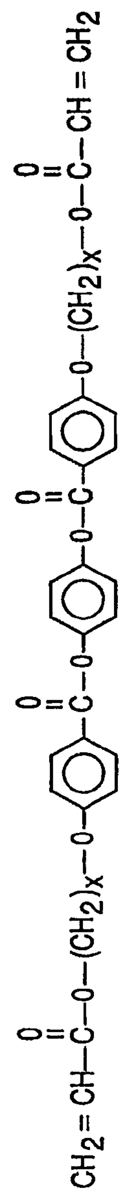

FIG. 2

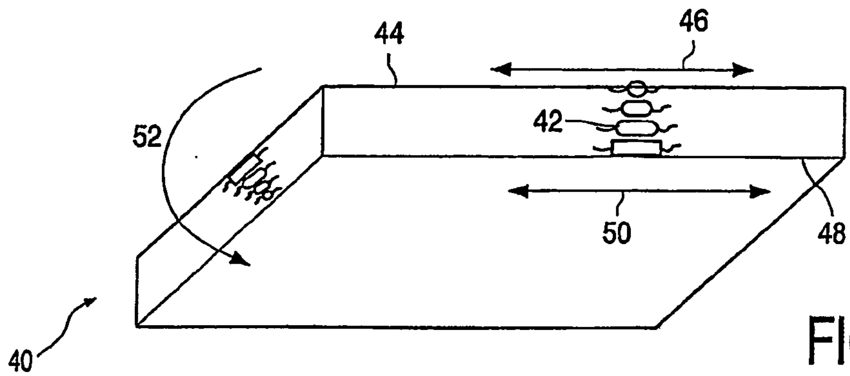

FIG. 4

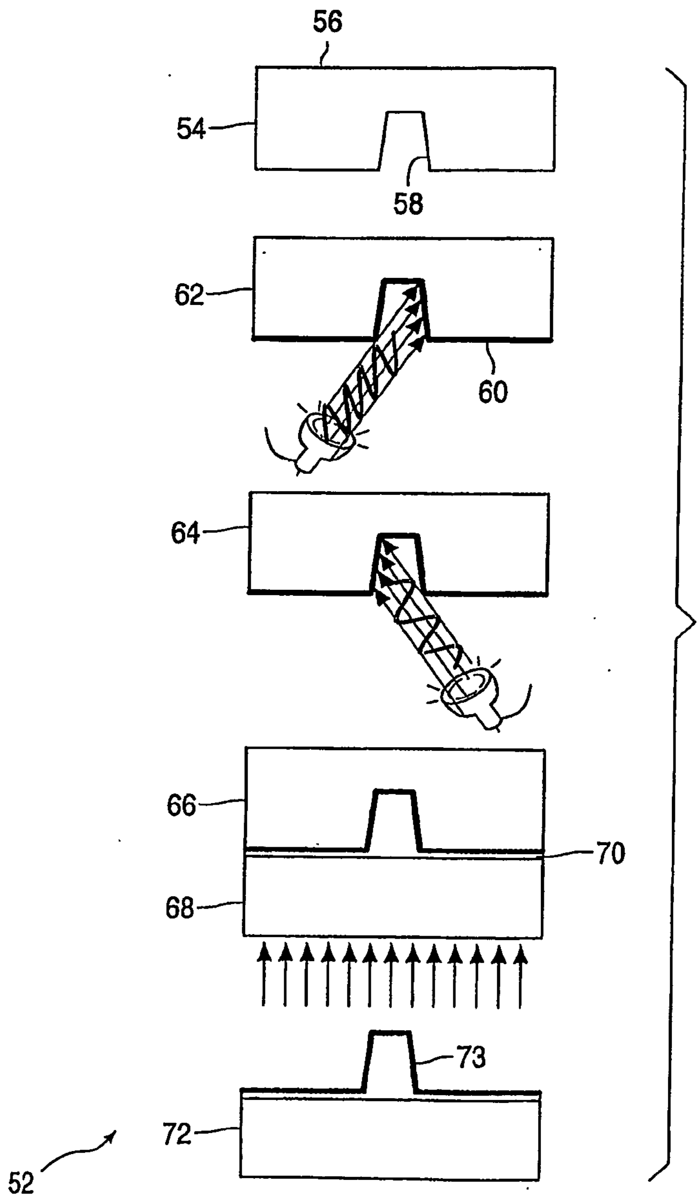

FIG. 5

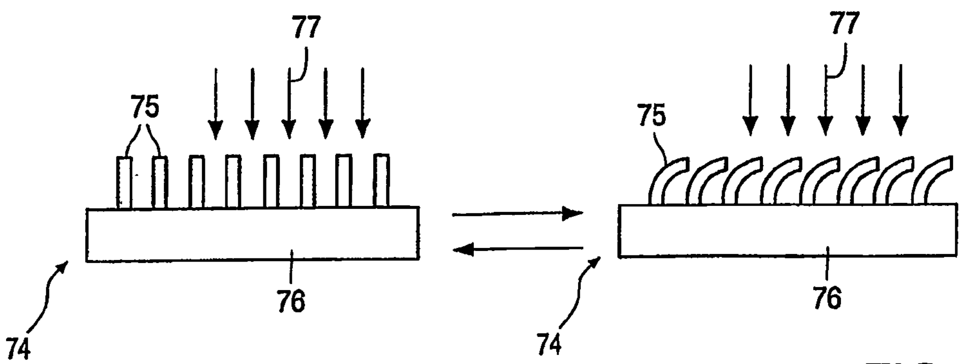
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FIG. 6

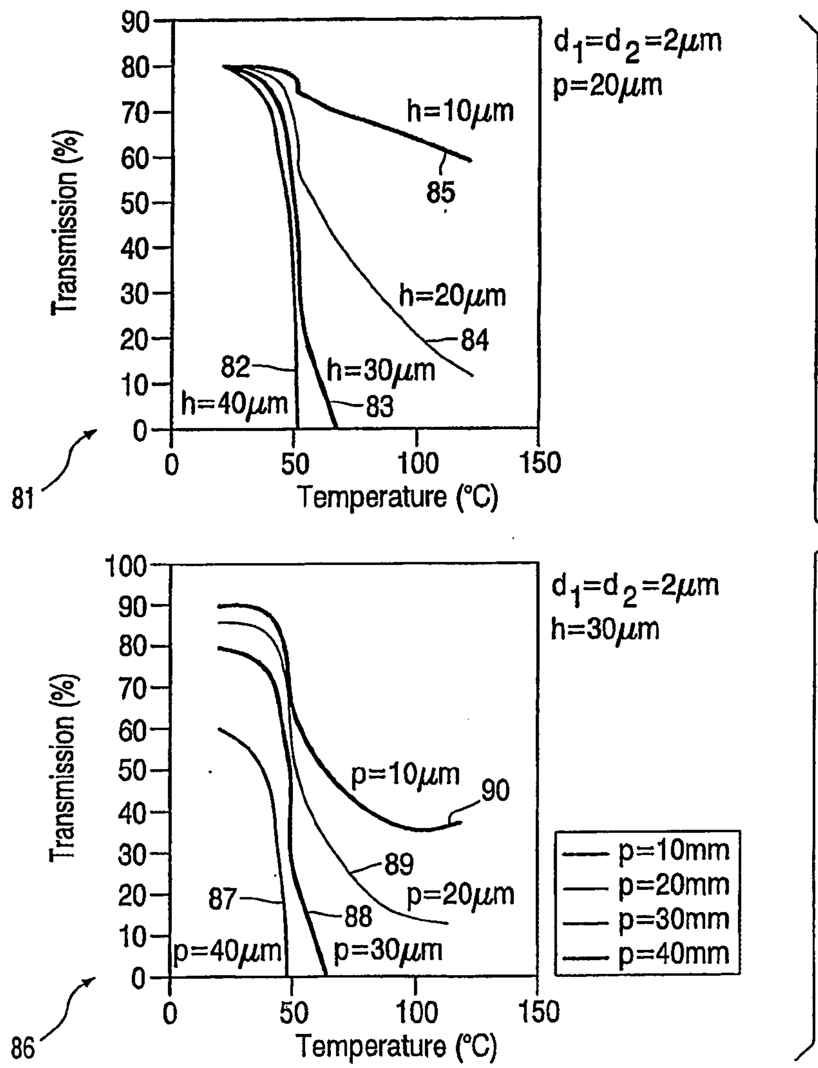
d1=d2=2μm
p=20μm
Transmission (%)
h=10μm
85
h=20μm
84
82
h=30μm
h=40μm
83
Temperature (°C)
81
d1=d2=2μm
h=30μm
p=10μm
90
89
p=20μm
87
88
p=40μm
p=30μm
p=10mm
p=20mm
p=30mm
p=40mm
86

FIG. 7